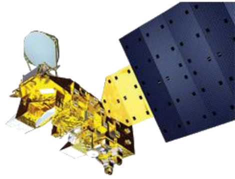
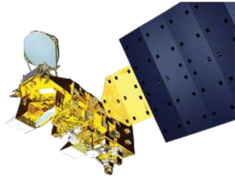


Change in the width of the ITCZ using 15 years of AIRS DCC data

Hartmut H. Aumann

AIRS Science Team Meeting

25 April 2018



Outline

- 1. ITCZ definitions
- 2. Theoretical expectations of changes in the ITCZ width
- 3. Metric of the strength of rain rates associated with DCC
- 4. AIRS observations of DCC as function of time and correlation with the tropical ocean mean SST.
- 5. Sensitivity of the ITCZ width to a warming climate based on the anomaly time series analysis
- 6. Sensitivity of the ITCZ width to a warming climate based on the anomaly time series correlation
- 7. Conclusions

The ITCZ is a band of intense rainfall that circles the Earth

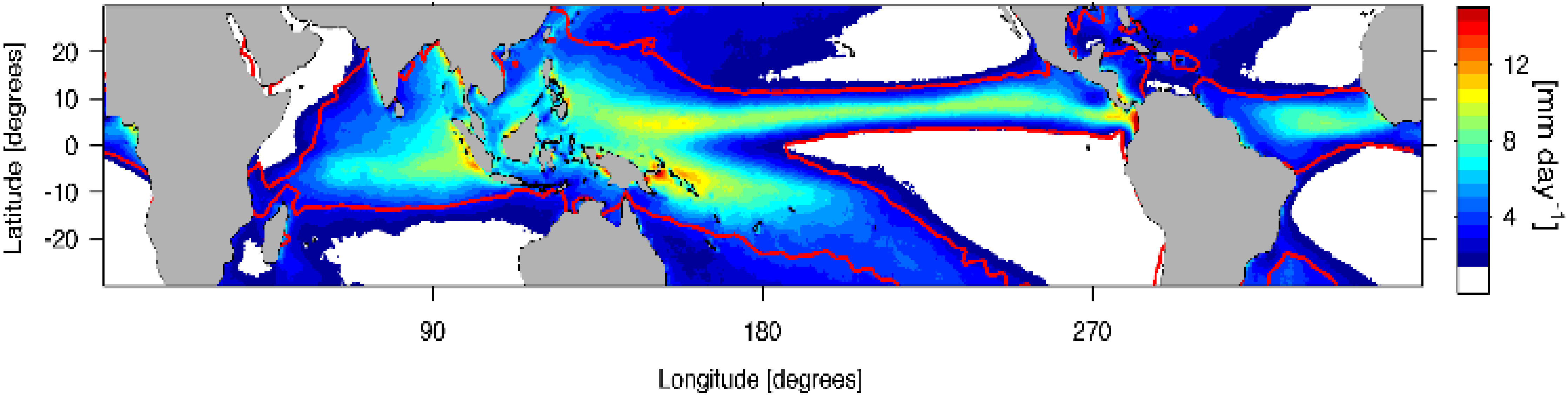
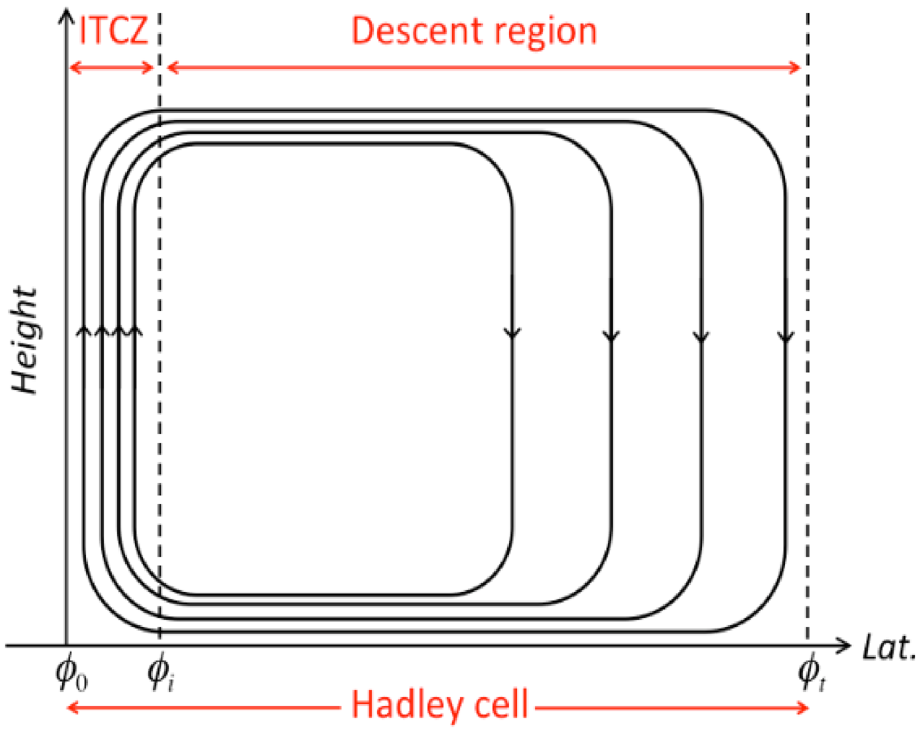
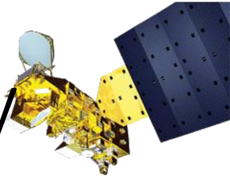


Figure 1. The observed ITCZ: Average precipitation rate (1998-2014) over oceans from the Tropical Rainfall Measuring Mission (colours). The red contour maps where the vertical velocity in the mid-troposphere is zero, i.e. the boundary separating regions of ascending and descending air in the tropics. Vertical velocity data are from the ERA-Interim reanalysis.



The ITCZ is located at the ascending branch of the Hadley cell, an atmospheric circulation associated with rising air near the equator and descending air in subtropical regions. This suggests a simple definition of the ITCZ width – as the portion of the Hadley cell where there is rising air.

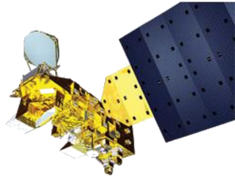
There is no unique definition of the ITCZ boundary



Since rainfall is associated with rising air, the edge of the ITCZ bounds the regions of heaviest rainfall in the tropics.
The numerical boundary depends on the rain rate threshold.

Cloud tops colder than 225K are associated with intense rain rates.
The numerical boundary of the cold cloud based ITCZ depends on the cloud-top temperature threshold.

Theoretical expectations



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Energetic Constraints on the Width of the Intertropical Convergence Zone

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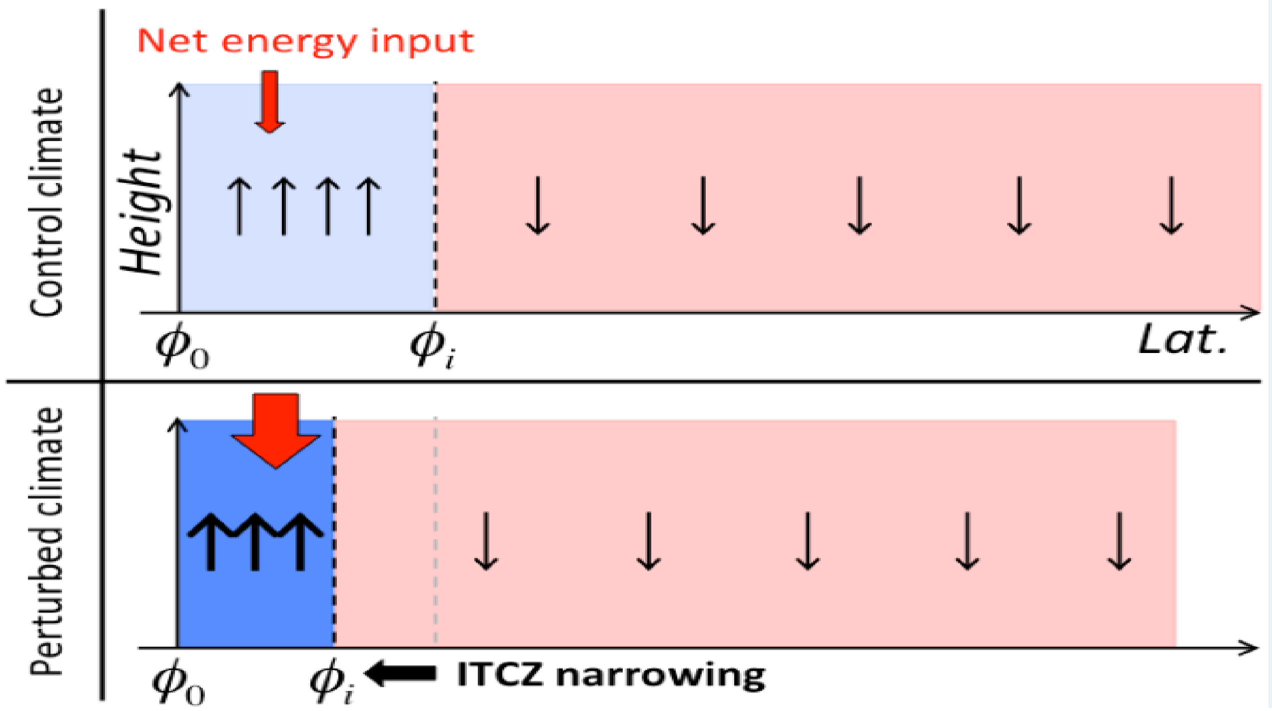
ABSTRACT

The intertropical convergence zone (ITCZ) has been the focus of considerable research in recent years, with much of this work concerned with how the latitude of maximum tropical precipitation responds to natural climate variability and to radiative forcing. The width of the ITCZ, however, has received little attention despite its importance for regional climate and for understanding the general circulation of the atmosphere. This paper investigates the ITCZ width in simulations with an idealized general circulation model

The paper argues that if the Net Energy Input increases, the width of the ITCZ will decrease



An increase in net energy input to the ITCZ in a perturbed climate (via reduced outgoing longwave radiation due to increased carbon dioxide concentrations, for example) means that, for energetic balance, the circulation and vertical velocity in the ITCZ must strengthen in order to export the excess energy (assuming the gross moist stability in the ITCZ is positive and constant). From the mass budget of the Hadley cell, an increase in vertical velocity in the ITCZ implies a narrowing of that region relative to the descent region

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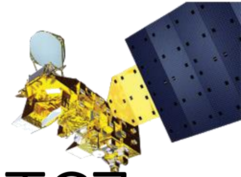
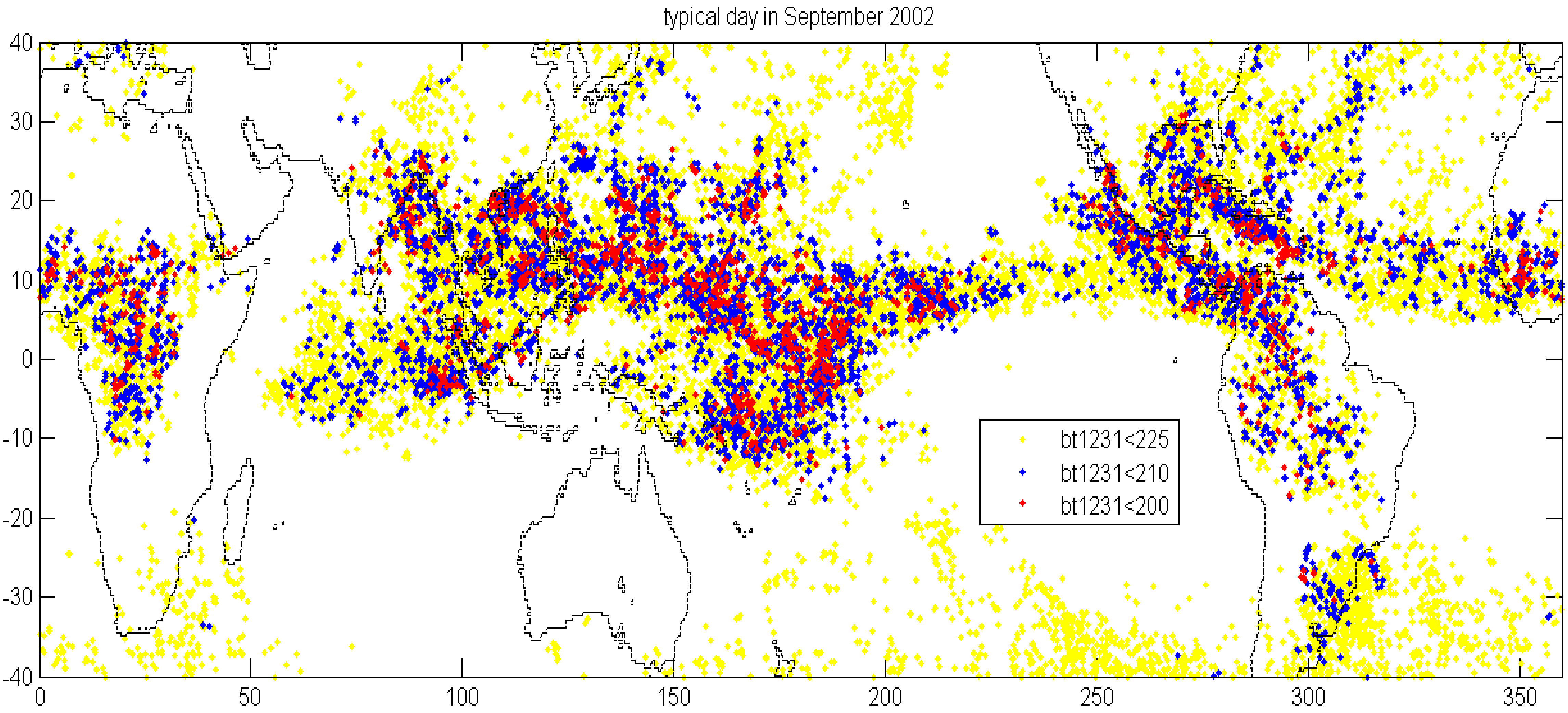
We use cloud tops colder than 225K from AIRS in the AIRS Climate Data Subset (ACDS) to characterize the ITCZ





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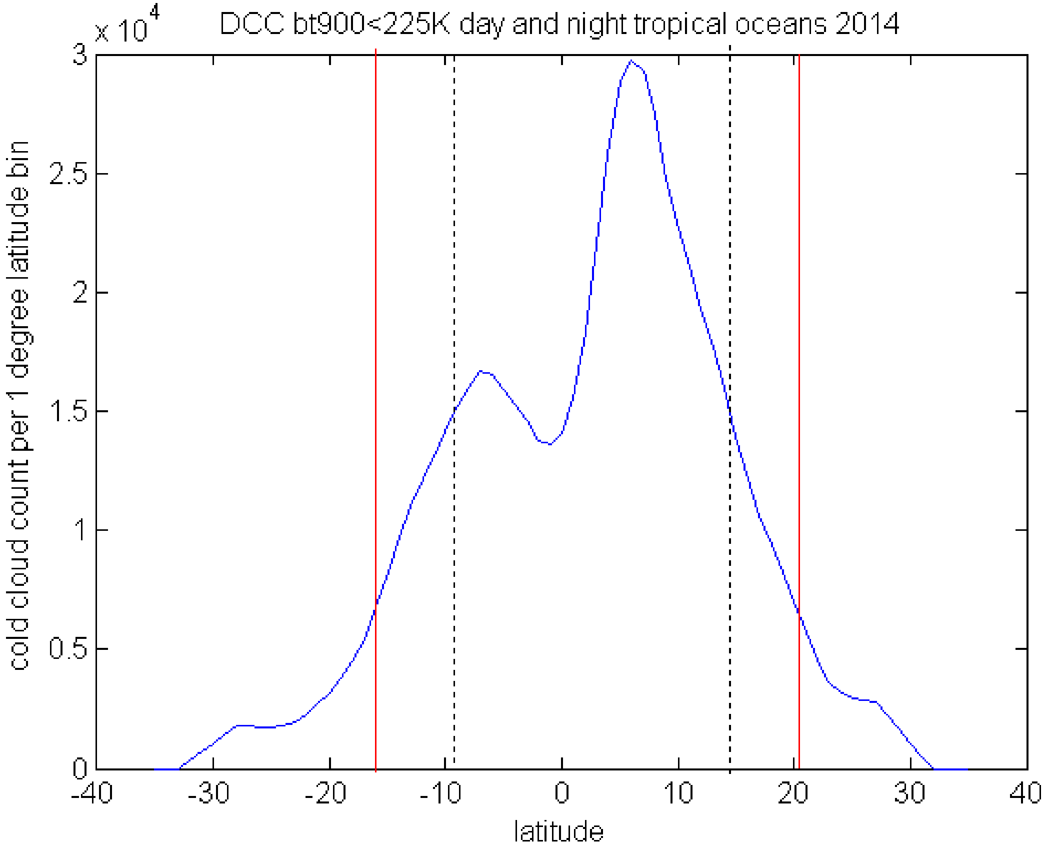
There is no unique definition of the ITCZ boundary

The location of the ITCZ can be defined using the PDF of the longitude averaged latitude of heavy rain or cold cloud tops.

The width of the ITCZ is the width of the PDF.
The numerical value depends on the definition of "width" of the PDF.
½ peak, +/- 1 sigma width (84-16 percentile),
or +/- 2 sigma width (95-5 percentile)

In the example from 2014 AIRS cloud tops colder than 225K the 16/84 width is 24 degrees (black dashed lines)
the 5/95 width is 36 degrees. (red lines)



There is consensus based on TRMM rain rate that the average width of the ITCZ is about 25 degree in latitude. Our analysis focuses on 225K clouds with the 16/84 width, but did the analysis using 225K, 210K and 195K cloud tops with the 5/95 and 16/84 definitions.

We use bt900< 225K, 210K and 195K thresholds and the 16/84 and 5/95 width for the calculations.

	bt900<225K	bt900<210K	bt900<195K
area of the tropical ocean	1.5%	0.5%	0.1%
AMSRe rain rate [mm/hr]	1.4	2.5	4.1
16/84 PDF latitude width [degree]	20.4	17.5	13.7
5/95 PDF latitude width [degree]	35.4	27.6	21.0

Table 1. Dependence of the width of the ITCZ on the DCC threshold and the definition of width.

The colder the cloud top the more it rains and the narrower the ITCZ.
Based on TRMM data the width of the ITCZ is 25 degrees.

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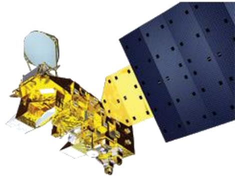
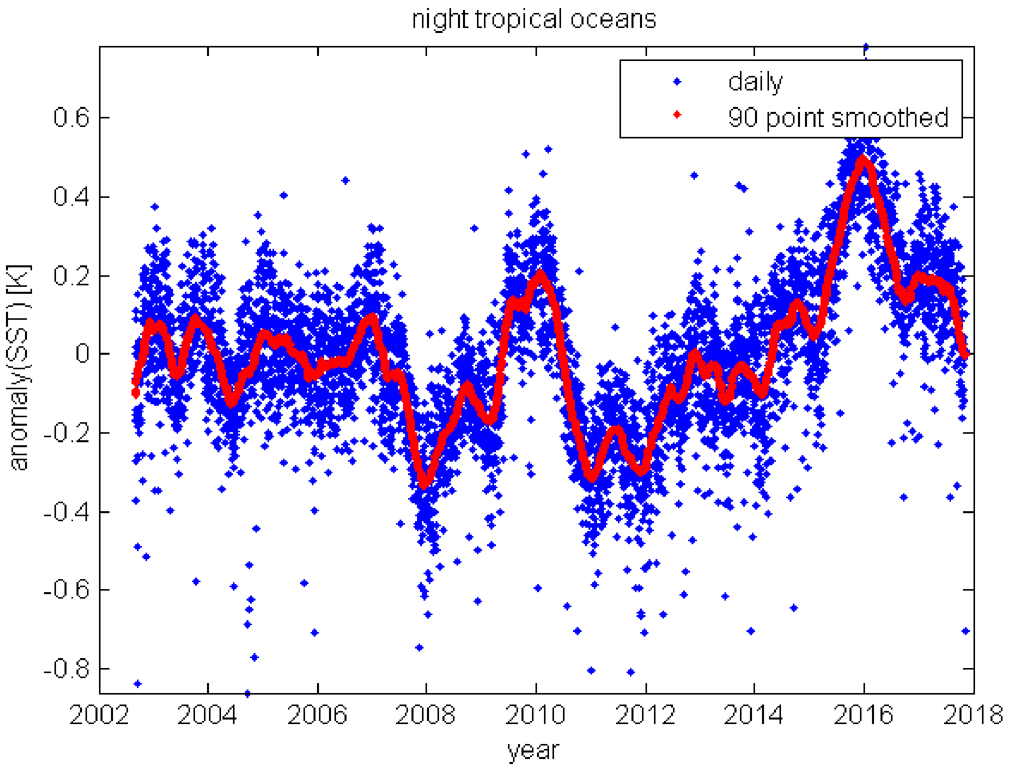
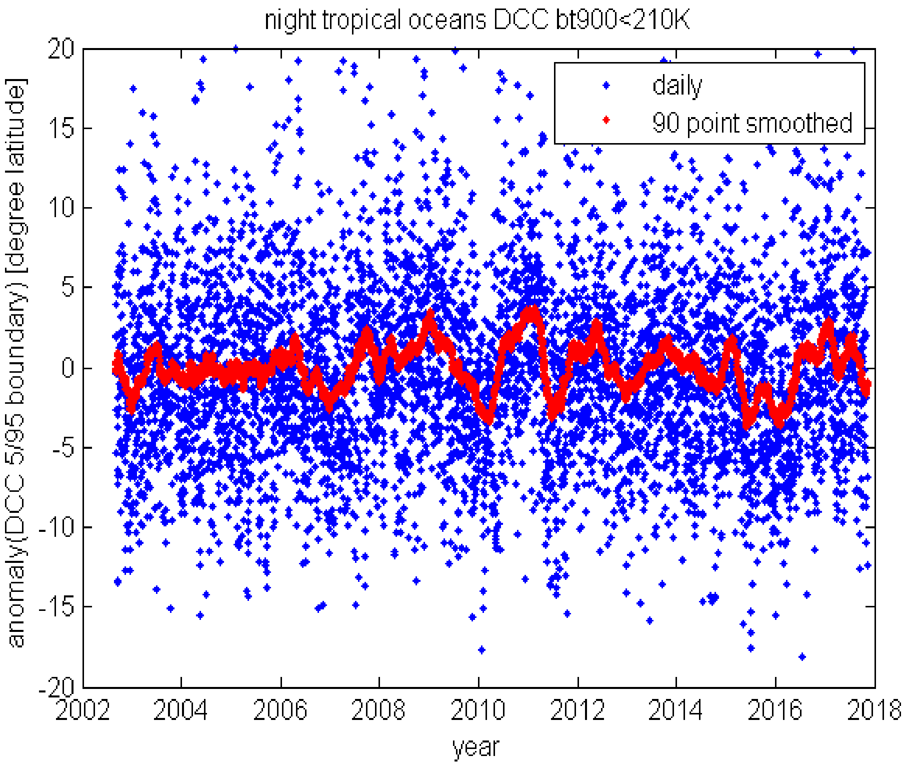
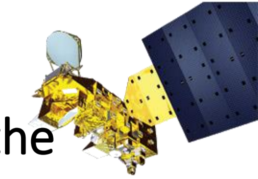


Anomaly trends from 2002-2016 show an anti-correlation between the mean SST and the width of the ITCZ







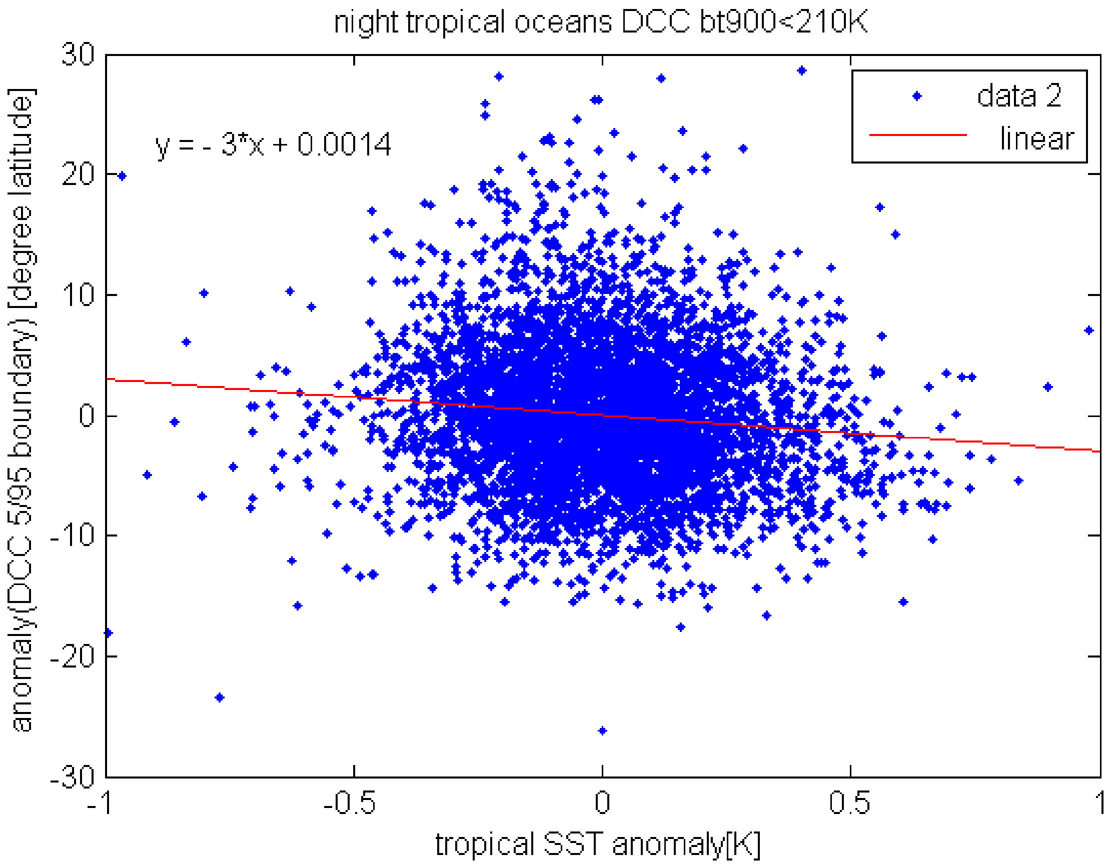
The sensitivity of the width of the ITCZ to a warming ocean [degree latitude/K] can be deduced from the ratio of the anomaly trend [degree/year] and the anomaly trend in the SST [K/year]

	bt900<225K	bt900<210K	bt900<195K
area of the tropical ocean	1.5%	0.5%	0.1%
AMSRe rain rate [mm/hr]	1.4	2.5	4.1
16/84 PDF latitude width [degree]	20.4	17.5	13.7
5/95 PDF latitude width [degree]	35.4	27.6	21.0
16/84 width anomaly trend [degree/year]	-0.030±0.015	-0.004±0.016	-0.001±0.022
5/95 width anomaly trend [degree/year]	-0.059±0.021	-0.002±0.020	-0.009±0.021
tropical SST anomaly trend [K/year]	+0.015±0.0007	+0.015±0.0007	+0.015±0.0007
16/84 anomaly ratio [degree width/K]	-2.0±1.0	< 1	< 1
5/95 anomaly ratio [degree width/K]	-4.0±1.5	< 1	< 1

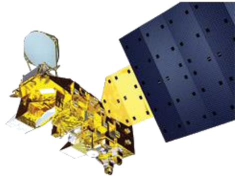
Table 2. Changes in the width of the ITCZ using DCC based on the time series analysis.

Only the bt900<225K cases create significant estimate of the sensitivity of the width of the ITCZ, -3 degree/K

The sensitivity of the width of the ITCZ to a warming ocean [degree latitude/K] can be deduced from the slope of the scatter diagram of anomaly of the width [degree latitude] and the anomaly of the SST [K].



For a 25 degree width of the ITCZ we find a sensitivity of -3 degree latitude/K



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16/84 anomaly ratio [degree width/K]	-2.0±1.0	< 1	< 1
5/95 anomaly ratio [degree width/K]	-4.0±1.5	< 1	< 1
16/84 width sensitivity [degree/K]	-3.1± 0.45	-2.19±0.33	-0.93±0.42
5/95 width sensitivity [degree/K]	-3.9± 0.85	-2.97±0.33	-1.26±0.37

Table 3. Changes in the width of the ITCZ using DCC based on the anomaly correlation analysis.

Summary

On theoretical grounds the width of the ITCZ is expected to decrease in a warming climate.

We use 16 years of AIRS observations of cloud tops colder than 225K to show that width of the ITCZ decreases by about 3 degree in latitude per degree K of warming of the tropical oceans.

The width of the ITCZ depends on a variety of physical processes, some of which are neither well understood nor well simulated by climate models (e.g., clouds).

We are starting to evaluate which of the CMIP5 models agree with the observations